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SEWAGE STABILIZATION PONDS. PUBLIC HEALTH AND VECTOR CONTROL ASPECTS

Bayard F. Bjornson

Communicable Disease Center
Atlanta, Georgia

1961

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SEWAGE STABILIZATION PONDS

PUBLIC HEALTH AND VECTOR CONTROL ASPECTS

Bayard F. Bjornson, Sanitarian

INTRODUCTION

In recent years, the use of sewage waste stabilization ponds (also called oxidation ponds or waste stabilization lagoons) for treating sewage wastes of communities has increased considerably. This increase has been particularly pronounced in the Dakotas and other Missouri River Basin states, and in Texas and southwestern states. Reports from a 1959 survey sent to all state sanitary engineers revealed that 652 United States cities were using sewage stabilization ponds.[1,2]

Several factors contributed to the expanded use of this waste disposal system. Among these were the need for more economical sewage disposal systems, and a growing trend toward water conservation and reclamation. Many engineering experts feel that stabilization ponds offer an effective and economical answer to community sewage disposal problems, particularly for small communities. The moderate per capita cost of construction, operation, and maintenance, as compared with conventional methods of treatment, is the major reason. Another reason is that skilled personnel, necessary to operate properly the more complicated conventional treatment facilities, often are not obtainable in small communities. Sewage stabilization ponds have been adapted for successful use under highly varying conditions.[3] They can be designed to provide intermediate, secondary, or higher levels of sewage treatment.

For public health reasons, it is essential that ponds be designed, constructed, and managed properly. Larvae and pupae of Culex tarsalis, the chief vector of Western encephalitis and rural St. Louis encephalitis have been found in the stabilization ponds of the Dakotas in greater numbers than those of any other species of mosquitoes. This mosquito, and also Culex quinquefasciatus, (considered an important vector of urban St. Louis encephalitis,) have been found in ponds and pond seepage pools in Texas. In both instances, investigators reported that mosquito production need not have occurred if the ponds had been designed and managed properly.

It appears, due primarily to economics, and secondarily to conservation, that the use of sewage stabilization pond systems will continue to expand for some time. The main objectives of this article are to make available to more sanitarians a knowledge of (1) some of the prin-

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ciples of design, operation and maintenance; and (2) the public health implications of these ponds.

HISTORY

Asia and Europe

In some Asian and European countries sewage has been added to ponds for fish cultivation for centuries. In Germany, valuable crops of fish have been grown in such ponds for the past half century.[4] In both Asia and Germany, as well as Sweden and Australia, the value of ponds for producing fish was discovered before their importance as a means of sewage disposal.

United States

In the United States, Texas has recorded the earliest use of photosynthetic action in the stabilization of sewage. San Antonio is reported to have used this process as early as 1901.[5,6] In California, photosynthetic stabilization was first studied at Santa Rosa in 1924.[5] The success of these early operations is probably responsible for the more than 250 installations in the southwest today.

In the Northern Plains area, the community of Fessenden, North Dakota has been depositing raw sewage in a slough west of the city since 1928. However, the first stabilization pond that was expressly designed for sewage disposal in North Dakota was constructed at Maddock in 1949. Favorable results of studies that were made there led to the endorsement of this method of sewage disposal by the North Dakota Department of Health, and also led to the subsequent use of the method throughout that State and the adjacent states.[5,7] A recent count showed 300 installations in the Missouri Basin. North Dakota and Missouri each have approximately 100 installations.[3] The United States had 652 sewage stabilization ponds in 1959.[2]

Canada

The use of stabilization ponds has also spread north into Canada. In 1956, there were 17 municipal installations in Saskatchewan. The populations of the cities that use them range from 600 to 3,000. The use of these ponds is spreading, and at least six more were under construction in 1957.[8] Kay, in 1958, reported a total of 60 ponds in Saskatchewan and Manitoba, and about 80 in Alberta.[9]

BASIC OPERATION PRINCIPLES

A sewage or waste stabilization pond is a structure that is designed to use natural biological, chemical, and physical processes to treat organic wastes. Basically, the sewage stabilization process consists of the complex interactions of bacteria and algae. Biochemical

oxygen demand or BOD, is a measure of the response of microbial growth to the nutritional character of organic matter. Bacteria digest and oxidize the organic components of sewage. Algae use carbon dioxide, ammonia, and other nutrients resulting from bacterial action to form cell protein by the photosynthetic process..[3,10] The carbon is used by the algae to produce carbohydrates and the oxygen that is released to the water is used by aerobic bacteria.[11] The amount of carbon present is usually the limiting element in the sewage stabilization process. However, it is not desirable to introduce it artificially to promote the photosynthetic production of oxygen.[12,13]

The objectionable characteristics of sewage essentially disappear during the retention period. This period ranges from three to four days in experimental aerobic ponds to between 25 and 120 days in conventional anaerobic ponds.[3]

The amount of photosynthesis that may occur in a stabilization pond is limited because there is a maximum intensity of light that algal cells can use during a given period. Thus, light supplied at higher intensity is partly wasted.[12]

Solar radiation is one important factor influencing the course and speed of the sewage stabilization process. Regional variations of sunlight are governed by latitude, elevation, and cloud cover. Seasonal and even daily variations are also significant. Penetration of incident light determines how much of the pond volume will participate in oxygen production - the key to freedom from nuisance conditions. Pond loading and algal density directly affect light penetration.[14,15] Research indicates that for a BOD content over 300 parts per million, light, not nutrition, is the limiting factor for outdoor algal growth. Wastes with a BOD over 300 parts per million need depths so shallow that pond areas have to be extensive.[10] The rate of photosynthetic oxygen production drops off rapidly with depth, and corresponds somewhat to the decrease in light.[15] It has been demonstrated that the amount of light used by algae is increased by vertical mixing.[16]

With detention periods of three or four days and optimum temperature and light, almost all the available ammonia nitrogen reacts with other compounds to form algal cell material. It has been observed that a waste containing 30 parts per million of nitrogen will support 300 parts per million of algal cells before the nitrogen becomes a limiting factor of cell growth. Since substrates vary in nutrient content, further research is needed to determine whether a given domestic sewage will support enough algal growth to meet its oxygen requirements for photosynthesis.[10,12]

Algal activity is almost negligible under ice cover due chiefly to reduced light penetration. Stabilization is accomplished by physical action (chiefly sedimentation) and anaerobic bacterial activity. BOD removals in Dakota ponds ranged from a low of 43.6 percent under the ice to a maximum of 98.4 percent in open water. Odor problems sometimes occur

in spring at the time of transition from ice cover to open water (change from anaerobic to aerobic activity) due to presence of anaerobic, septic sewage.[5,9,16] Sodium nitrate at the rate of 100 pounds per acre per 24 hours for a few days has been recommended to control odors during this critical period.[9]

Temperature is very important in the stabilization process. It markedly affects the rate of BOD reaction by influencing algal respiration and also by affecting the dissolved oxygen saturation value.[3] Some wind is desirable because it causes wave action and provides for surface aeration and the mixing of dissolved oxygen throughout the liquid contents of a pond.[16]

DESIGN

Many factors must be taken into consideration in the design and construction of sewage stabilization ponds. Though this method is a simple type of sewage treatment, it is essential that ponds be designed by persons who have a thorough understanding of the biological-chemical-engineering factors involved. Ponds can be designed, and operated under widely varying conditions, to perform all the functions of present day complete sewage treatment plants.

Oswald refers to three categories or types of sewage stabilization ponds. They are:

1. Aerobic - high rate ponds in which the stabilization action is entirely aerobic,

2. Anaerobic - ponds that may contain oxygen, but the major volume of the pond and action of stabilization is anaerobic,

3. Facultative - ponds that are intermittently anaerobic and aerobic.[10]

Ponds should be designed on the bases of population to be served, evaporation and percolation rates, and the amount of industrial wastes to be handled in addition to domestic sewage.[1,4,16,18,19,20,21] Installations are now successfully serving oil refineries, slaughterhouses, dairy product plants, poultry handling processors, and rendering plants. Special study should be given to units that are being designed to treat significant amounts of industrial wastes.[3,22] Ponds serving combined storm and sanitary sewer systems may need grit removal facilities to prevent interference with influent discharge and water circulation.

A preliminary engineering report should include site selection, land cost, soil composition, number of pond units, and type of installation (series or parallel). It should include information such as surface runoff, dike construction, bottom construction, influent lines, overflow structures, and interconnecting piping.

In areas with warm, dry climates, and porous soils, evaporation and percolation may present problems. For example, in Texas, evaporation losses range from 56 to 120 inches per year.[5,11,16,17] Variable factors such as sunlight, wind, temperature, rainfall, ice cover, and strength and type of sewage, must be considered.

Location

Ponds should be located as far away from business or residential areas as is reasonably practicable and economically feasible. However, experience indicates that ponds may be located as close to populated areas as any of the other sewage treatment processes. Plans should make future enlargement of the system possible. Sites permitting unobstructed wind action over the water surface and a safe distance from ground water sources are desirable. Except for fissured rock or coarse gravel formations, the travel of bacterial contaminants through a significant horizontal distance in soil is not considered probable.[3]

Construction

Ponds are constructed by building embankments to form round, square, or rectangular basins of the desired size and number in parallel or series. Length should not exceed three times width.[3] Irregular shorelines should be avoided as they provide protected areas where floating materials accumulate.[16] Dikes should be rounded at the corners to minimize this. They should be so constructed as to prevent the pond from receiving significant amounts of surface runoff and to prevent excessive seepage from the units. Inner slopes should be steep enough to reduce erosion by wave action. Slopes of three or four horizontal to one vertical are commonly recommended.[3,16] Dikes should be of sufficient width to accommodate mowing, spray, and maintenance equipment and should be seeded on the outer slope to minimize erosion.[3] A freeboard of three feet minimum is generally recommended.[5,9,16] The pond bottom should be made as level as possible.

Fig. 1. Banks are clean and steep - bottoms level. Too many trees hinder wind and wave action.

Influent lines should discharge horizontally; preferably by gravity, and far enough from any bank to insure minimum interference with normal circulation. In large installations multiple inlets appear to disperse solids more uniformly than single inlets.

Overflow structures should be designed to permit operation of the pond or ponds at selected depths. They should permit lowering the water level at a rate not less than one foot per week and complete draining of each pond should be possible. Subsurface withdrawals may be desirable to

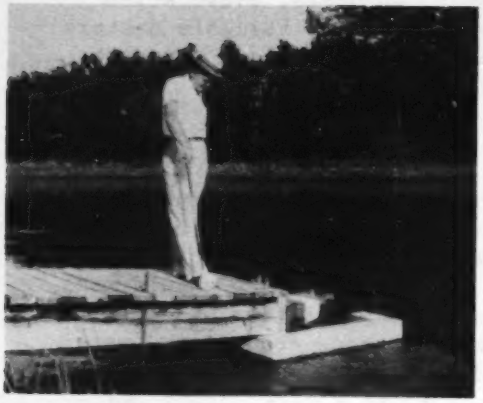

Fig. 2. Overflow device.

Fig. 3. Close-up of overflow device in Fig. 2.

exclude algae from the effluent.[16] In multiple unit installations, valving or other arrangements to regulate flow between ponds is recommended. In northern climates, the overflow structures must be so constructed that ice formation will neither stop the overflow nor damage the structure.[3,16]

BOD and Hydraulic Loadings

Missouri River Basin States often design ponds by calculating pond area based on expected BOD and hydraulic loadings, but Hermann and Gloyna feel these loadings should be based on pond volume rather than area.[3,19] Area and loadings are influenced by many factors, including: water use per capita, evaporation, rainfall, seepage, the degree of treatment desired, growth prospects, and the basic operating plan for the facility. Smaller ponds are better for locations where land is expensive, but would require more efficient use of photosynthetic oxygen production than larger ponds. Large deep ponds with long detention times require little control. If turbidity is equal, small, shallow ponds are much more efficient as they use sunlight much more effectively. Oswald and Gotaas found that the load factor was greater for shallow ponds (18 inches) than for a pond of 36-inch depth.[10] Loadings of facultative ponds range from as low as 10 pounds of five-day 20°C. BOD per acre per day in the northern states to as high as 80 pounds in southern states,with an average between 30 and 50 pounds. The A.P.H.A. Sewage Disposal Committee in 1948 recommended a minimum surface area of one acre for each 400 individuals of a contributory population. Present day experimental aerobic ponds handle 60-65 pounds of BOD per acre per day. Oswald estimates that future "high rate" aerobic ponds of one acre size will handle the wastes of approximately 1000 people, or about 160-200 pounds of BOD per acre per day, which is many times the rate of conventional ponds. Such ponds will develop dense enough algal growths to supply nearly all oxygen requirements.[3,16,18,22,23] In cold climates, where ice cover slows waste treatment, it may be desirable to retain all winter-time sewage flow. Then retention may serve as a basis of design rather than BOD loadings.

Retention Period

Caldwell recommends a minimum retention time of 25 days for facultative ponds.[22] Flow-through ponds receiving raw sewage in Missouri River Basin States normally employ a 60-day retention period with as many as 90-120 days occasionally specified. A high degree of coliform removal is obtained even with 30-day retention in facultative ponds. The pond effluent will sometimes contain as much organic material as the sewage influent. The incoming sewage is highly putrescible and hazardous to public health whereas the algal cells in the effluent are highly stable and have no pathogenic significance. Algae provide a source of food for fish and wildlife. Stabilization ponds have clearly demonstrated ability to satisfactorily treat substantially higher loadings in the summer, making them particularly appropriate for resort areas.[3] Oswald and Gotaas concluded retention periods for "high rate" aerobic ponds should not be less than one day in summer and six days in winter.[10]

Parallel and Series Operation

Many installations provide flexibility in volume and loading factors by designing ponds to operate either in series or parallel. This permits running the entire sewage discharge into a single unit in areas: (1) in which loading is light, (2) of low water usage, (3) of high evaporation, or (4) of considerable seepage. Such installations usually permit increased loadings as populations increase. The Missouri Basin Engineering Health Council recommends designing two or more units for both series and parallel operation, except for installations six to eight acres or less.[3] Reducing individual pond size will reduce wind effects. This is an advantage from the standpoint of dike erosion, but a disadvantage from the standpoint of mixing pond contents.[16]

Fig. 4. These stabilization ponds operate in series. Note fencing in background.

Excellent BOD removals can be obtained by operating two ponds in series; the first anaerobic and the second aerobic. This arrangement may not prove satisfactory for heavily populated areas because of excessive odors and unsightly floating matter in the anaerobic pond if overloading occurs. Series operation is particularly effective to obtain a high level of BOD and coliform removal.

Depth

Hermann and Gloyna found optimum depths for facultative ponds in Texas ranged from two feet to three and one-half feet.[19] The A.P.H.A. Committee

on Sewage Disposal in 1948 recommended a three-foot depth.[23] Beadle and Harmston recommend a four-foot depth to discourage weed growth and mosquito breeding.[24] Towne and Davis believe it desirable to provide for varying the operating depth from two and one-half to five feet.[16] Optimum depth for photosynthetic oxygenation at Richmond, California in experimental aerobic ponds was 21 inches in summer and 11 inches in winter with detention periods of four and five days, respectively. These four or five day detention periods are much shorter than those presently required at operating field installations, particularly those processing raw sewage. Oswald et al. doubt if detention periods would vary much with geographic location but optimum depths would vary depending on the latitudes and climate.[18] Shallow ponds permit maximum penetration of sunlight for algal growth, but they have the disadvantage of permitting growth of rooted aquatic plants which may cause trouble and encourage mosquito breeding.[22] Relation of depth to size of pond should be such as to facilitate circulation within the body of water. Facilities to adjust pond levels can be provided at little increase in cost and permit operational flexibility.

Fig. 5. Heavy infestations of cattails or weeds encourage mosquito development.

Temperature and Wind

Studies of Hermann and Gloyna indicate that with respect to (a) waste stabilization, (b) required detention time, and (c) volume of the pond, temperature is the most important factor in the operation of anaerobic-type ponds. Temperature affects the stabilization process chiefly because of its effect on the rate of BOD reaction, including algal respiration, and on the dissolved oxygen saturation value. Hermann and Gloyna concluded that intrapond recirculation is not warranted by improvement of BOD removal, and that continuous interpond circulation is not worthwhile. However, they suggested that it is desirable to have facilities that will permit rapid transfer of large quantities of water from one pond to another in order to change algal concentrations, or to adjust pH from time to time.[3,19]

The wind velocity required for good mixing is believed to be related to pond size. It was observed in studies of Dakota ponds that winds over 30 miles per hour caused noticeable waves. A disadvantage of wave action is greater erosion of shorelines.

Evaporation, Precipitation, Seepage

In order for a stabilization pond to have an overflow, the sum of influent sewage plus precipitation must be greater than the sum of evaporation plus seepage through the pond dikes and bottom. Pretreatment of

dikes and bottom to make them relatively impermeable may be in order where seepage and evaporation are excessive.[16]

Fig. 6. Insufficient depth of water due to excessive pond size and percolation.

Fig. 7. Emergent vegetation ideal for mosquito development.

Figure 6 shows a stabilization pond with insufficient depth of water due to excessive pond size and percolation. Shallow water and emergent vegetation shown in Figure 7 are ideal for mosquito development. To correct this condition, the pond area was reduced by diking, and the bottom of the pond lined with clay, see Figures 8 and 9.

Fig. 8

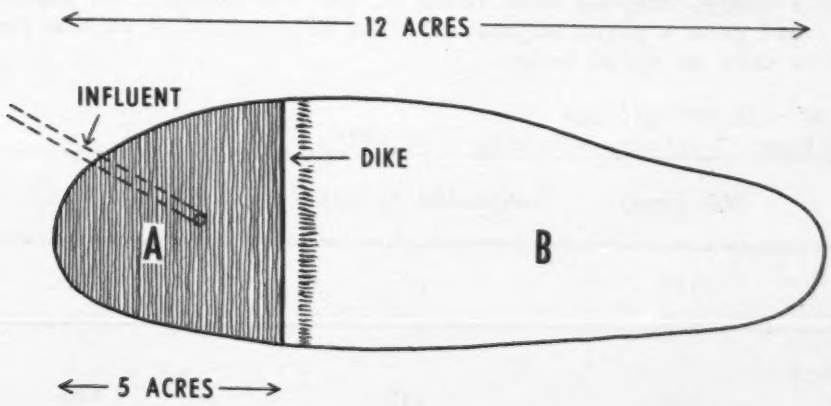

Fig. 9

Pond Lining

Oswald and Gotaas feel there may be advantages to lining "high rate" aerobic ponds with asphaltic or rubber membranes, as vertical mixing -

considered essential for raising precipitated sludge to the surface for increased light utilization - might cause turbidity which in turn can either reduce or end light usage. Advantages of having a lining would be better light utilization and discouragement of weed growth. If a lining is used, estimated minimum feasible pond size will be one-half acre per 1,000 population. Oswald and Gotaas also conclude that a decision on linings hinges mainly on the value of harvested algae.[10] Howells and Dubois, 1959, gave cost figures on some clay lining materials:

MATERIAL	THICKNESS OF LAYER	COST
Bentonite clay	0.5 lb./sq. yd.	18¢/sq. yd.
Bentonite clay	9 lb./sq. yd.	20-50¢/sq. yd.
Native clay (bid cost)	6"	$8\frac{1}{3}$¢/sq. yd.

Operation

The operation of a pond is simple. Essentially, it consists of merely changing influent locations as necessary, periodic removal of weeds from banks, and mosquito control. Removal of vegetation will help to control mosquitoes.[5,11,17,22]

APPLICABILITY FOR SMALL INSTALLATIONS

According to Gidley, ponds are also adaptable for small communities and rural installations. When the sewage facilities of a TB sanitarium in West Virginia became overloaded due to expansion from a 100 to a 240-bed hospital, a pond was constructed to handle the additional treatment needs.[25] This pond had functioned well for 1½ years up to 1956, when his article was published.

In this study, samples were taken of the raw sewage, the septic tank effluent, and from a point adjacent to the effluent pipe of the pond. The results were as shown below:

DAILY FLOW - 30,000 gallons
Final Effluent Coliform Reduction - 99.97%

Sewage	BOD (ppm)	Suspended Solids (ppm)	Total Solids (ppm)
Raw	172	172	805
Septic Tank Effluent	112	135	488
Pond Effluent	8	138	319

Gidley concluded that secondary treatment of septic tank effluent by stabilization ponds can be used successfully where location and topography permit an economical installation. "The treatment appears to be well adapted to small installations involving a few hundred people."[25]

ECONOMICS

Cost of Pond Construction

Gloyna and Hermann listed six reasons why waste stabilization pond technology should be better and more fully understood: (1) ponds are economical, particularly for small cities; (2) if ponds are chosen, small cities then can devote their limited funds to expansion of waste collection, rather than to secondary treatment systems; (3) highly skilled personnel are not required to operate them; (4) reclaimed water may be used for badly needed irrigation, or other purposes; (5) ponds are more amenable to fluctuating loads and ground water infiltration than some other forms of secondary treatment; and (6) the convertible protein is a potentially valuable resource which, in time, will be used.[26]

Ponding is perhaps the most economical method available for secondary treatment of sewage. Other methods include the trickling filter, contact aeration, and the activated sludge method, which feature vigorous aeration to furnish essential oxygen to bacteria for their work on organic material.

Costs for pond construction are moderate compared with these conventional treatment processes.[27] Howells and Dubois reported little difference in costs between one and two cell stabilization ponds.[1] They found a high degree of correlation in construction cost data from three states when developed on the basis of cost per unit of surface area. Per capita costs for facultative ponds for communities from 500 to 1,500 population in the Dakotas ranged from $4.40 to $37.94.[20] Oswald estimates the cost of a "high rate" aerobic pond at $10,000 per acre.

Algae

A number of genera of algae grow in sewage stabilization ponds. Some of the more important are Chlorella, Scenedesmus, Euglena, Chlamydomonas, and Phacus.[10,27,28,29,30,21,32] Sometimes decaying blue green algal scum forms on the surface of ponds restricting light penetration and causing odors.[10,22] It is reported that operating a boat equipped with an outboard motor once over the surface disperses the algal mats and controls odors for several months.[33] Harvesting the algae is expensive and has not been perfected as yet.[3,34]

Algae for Animal Food

Oswald and Golueke have tried several methods to find an economical means of removing and drying algae for animal food supplement from ponds at Concord, California. Two methods used were centrifugation and alum floculation followed by spray or drum drying, or drying the algae on

sandbeds.[27]

Sewage-grown algae are not so rich in protein as algae grown in other media, but nevertheless may be considered a valuable protein source.[32] In the sewage pond stabilization process, it should be possible to regain roughly 60 percent of the original human protein intake.[29] Algae have been evaluated as a protein food source in studies at the University of California and estimated to meet one-fifth of the nutritional requirements of chickens and to be worth about $100 per ton as a feed supplement.[10] Present production costs are about $80 per ton which compares favorably with current forage crops. The sewage from a town of about 10,000 might produce about 1400 pounds of valuable protein each day for future use as a basic portion of the diet of cattle, sheep, and chickens.

Water Reuse - Irrigation

In many areas of the world, the effluent of stabilization ponds is extremely valuable for irrigation use. For example, at Mojave, California, the reclamation of sewage waters in this manner has helped to conserve the native sources of water.[35] At Santa Rosa, California, pond effluent is used by farmers whose lands are adjacent to the plant. There, the irrigation season runs from June until late September.[36]

In Israel, further expansion of agriculture is limited by the amount of water available for irrigation. It has been proposed that sewage effluents be used to augment short water supplies. The total need for irrigation is estimated at 400 billion gallons in 10 years, chiefly in the Negev desert area located in the southern part of the Israel territory.[37]

Fish Culture

In some European and Asian countries, sewage is added to ponds to raise fish which are then sold as food. Carp thrive in such ponds, as do some game fish including rainbow trout, black bass, pike, perch, and tench. Rainbow trout have been raised from fry stage to 250-gram fish in one season. To raise these fish, BOD loading must be carefully regulated so that the fish are not endangered by depletion of dissolved oxygen. Gambusia affinis, the top minnow used to control mosquitoes, has been the chief fish grown in stabilization ponds in the United States.[4]

SPACE SURVIVAL

A very interesting side development of the stabilization pond research is the possible use of algae to produce oxygen and food for human beings in order to make long space flights feasible. This use may well prove to be the most far reaching application of research work on algae and stabilization ponds.

Oswald and Golueke presently estimate that 30 to 40 gallons of algae and water would be required per crew member. They believe, with refinements, this may be cut to about 15 gallons per man. Even the former figures would be less than the large amounts of water, food, and oxygen, plus equipment for removal of wastes that otherwise would be required.

The photosynthetic process previously outlined would be employed to convert human waste products, including exhaled carbon dioxide, to protein food, usable water, and oxygen. Protein rich algal pills could be used to supplement the spacemen's diet. Only some additional solid food and some sun to drive the "miniature earth" would be needed.[27]

PUBLIC HEALTH

The possibility of contamination of ground water supplies should be considered in selecting stabilization pond sites. Ground water aquifers, particularly those used for municipal water sources, should not be subject to contamination by seepage from such ponds. Detergents are a problem in this respect. Sound public health practice forbids contact of sewage with domestic water supply sources.[3,5,16,17,38]

Coliform Removal Efficiency

The Committee on Sewage Disposal of the American Public Health Association in 1948 reported on the favorable BOD removals of sewage stabilization ponds, "Such results continue day after day, and therefore will rank with or outrank the results from chlorination in reliability."[23] After removal of algae, the effluent from a properly designed and operated pond is comparable in removal efficiencies to that from a conventional sewage treatment plant. It might therefore meet State department of health regulations concerning the use of secondary sewage treatment plant waters for irrigation.[5]

Caldwell states that the efficiency of ponds in reducing coliform bacteria is believed to be related to anti-bacterial activity of some constituent of the algae.[22] Oswald and Gotaas contend that no anti-coliform activity could be credited to algae in the cultures that they tested. However, if the algae are chemically precipitated, practically all the coliforms are removed to the sludge and the effluent may be satisfactorily filtered through a rapid sand filter.[10] Towne et al. in studies of Dakota ponds, have reported no significant seasonal differences in bacterial numbers despite variations in algal content.[16] But, Smallhorst et al. conclude that long storage, with settling and severe competition, result in reduction of bacteria.[6] One other explanation for the reduction of bacteria is high oxygen levels and high pH of the water caused by the absorption of CO_2 by the algae. Although final bacteria removals are high as measured by the most probable number (MPN) of coliform, the hazard of contact with pathogenic bacteria in the sewage before it has become stabilized must be recognized.

Safety Precautions

Livestock and other domestic animals sometimes use sewage stabilization ponds as sources of drinking water. This practice should not be permitted until both the possibility of bacterial infection, and poisoning by certain algae that are toxic to animals, has been investigated and shown to be negative.[5,10,17] A large open body of water is attractive particularly to children. Instances of ice skating, boating and even swimming in ponds have occurred. Ponds are frequented by wild fowl, therefore hunters are drawn to them. No cases of infections among hunters have been reported from the Dakotas. Nevertheless, hunting and other recreational use of the ponds should be prohibited as a public health safeguard. Fencing, and signs indicating that the facility is a sewage treatment device, and prohibiting trespassing, are needed.[4,5,16,17,22]

Fig. 10. Pond areas are fenced to protect children and animals. Weeds should be eliminated.

Although they are of more aesthetic, than public health, importance, odors should be kept to a minimum. Sewage containing only a trace of dissolved oxygen is not offensive and does not produce hydrogen sulfide. Caldwell noted that odors will be noticed at considerable distance from the ponds when sulfide content exceeds two parts per million.[22] Wastes high in sulfates (above 750 ppm) have presented some problem of odors.[3] Septic areas in ponds are glassy and smooth though other areas have normal wave action. Modern detergents may also cause this glassy appearance. Where green coloration of algae is evident, dissolved oxygen will be present and offensive odors absent.[22]

Mosquitoes and Other Vectors

The rapid growth in popularity of stabilization ponds has raised some concern that they may be a public health hazard from the standpoint of mosquitoes. A special survey of Dakota installations was conducted in July and August 1956 by personnel from the Communicable Disease Center in Atlanta, Georgia. It was made in conjunction with studies to obtain knowledge of basic design, and operational criteria by personnel of the Robert A. Taft Sanitary Engineering Center and the North and

Fig. 11. Heavy breeding of *Culex tarsalis* associated with mowed cattail in this pond.

South Dakota Health Departments.[24]

In all, 26 ponds were surveyed, 14 in South Dakota, and 12 in North Dakota. The total represented 35 percent of the stabilization ponds in those States at the time of the survey.

Fig. 12. Clean, steep shorelines discourage mosquito production.

Eighteen, or 69 percent of the ponds were found positive for Culex tarsalis, considered the major vector of encephalitis in the western states. Of the 18 positive ponds, eight were rated as light infestations, two as moderate, and eight were rated as heavy infestations. Over 99 percent of tne mosquitoes collected were Culex tarsalis. Vegetation was present in every pond where mosquitoes were collected.

Fig. 13. Circular pond with clean shoreline. Note fence to protect animals.

The following recommendations were outlined for either preventing or correcting mosquito problems:

(1) Proper basic design and operation of ponds is essential.

(2) Weed growth must be prevented or controlled by cutting or use of herbicides.

(3) Ponds should be kept at a minimum depth of four feet during the mosquito breeding season.

(4) Embankment slopes must be steep.

(5) Access must be planned for spray equipment used for insecticiding operations.

(6) A means for rapid filling of water must be provided.

(7) Larvicides should be used as necessary.

It was concluded that "stabilization ponds with high vegetation had a high mosquito potential and those without vegetation, a low

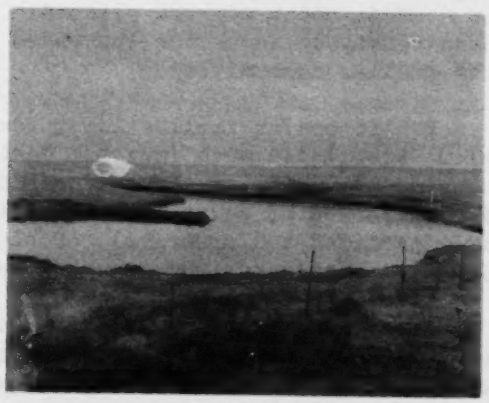

Fig. 14. Irregular shorelines cause excessive erosion, poor wave action and encourage weed growth.

mosquito potential." Beadle came to the same conclusions following a mosquito survey in Mississippi in July 1958 where moderate production of Culex erraticus was found in only one of nine ponds.[39]

Eads has reported, "In Texas, the extensive use of oxidation ponds for primary and/or secondary treatment of sewage has been shown to be an important factor in the production of encephalitis vectors, notably Culex tarsalis and Culex quinquefasciatus. The reduction of organic matter of sewage in these ponds by aerobic bacteria and algae has proven effective, economically feasible and in accordance with basic water conservation objectives. However, they have to be properly designed and managed to prevent mosquito breeding."

The ponds of 36 Texas cities were surveyed. Mosquito larvae were found in 22 or 61 percent of these systems. Mosquito breeding that resulted from discharge of the pond effluent to fields for irrigation or to creeks occurred at 16 of these cities' ponds. Pools of water formed by seepage from the ponds or rainwater were found at 11 installations.[40]

Van Heuvelen and Svore mention that dikes must be inspected for "bank rats and other animals, which would tend to undermine and break down the dike structure."[17] It is unlikely that Norway rats would become a problem unless ponds were overloaded and unprocessed floating organic material was continuously drifting to the banks and supplying rodents with a regular supply of food

SUMMARY

The use of stabilization pond systems for sewage treatment has expanded in many areas of the United States. Adherence to sound principles of construction and operation of these ponds is essential. Therefore pond development and performance should be supervised by a qualified engineer. Considerable research has been done in this field, but more is needed, under way and planned. Economic aspects and conservation considerations favor the increased use of this system, particularly by the smaller communities.

Public health implications, including mosquito and other vector problems associated with improper design and management, must be carefully considered. Many of the engineering experts in the design, construction, and operation of sewage stabilization pond systems feel that such systems are justified and practical. Public health hazards can be minimal if ponds are designed, constructed, and managed properly.

It appears that the use of sewage stabilization ponds will continue to expand, at least in the immediate future. Refinements in their operation will also be forthcoming and will be based on research findings. Sanitarians may contribute to the successful use of such pond systems in their communities by becoming familiar with them and by helping to minimize

the health hazards that are connected with improper design, construction, operation, and maintenance.

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